

### Remarks

The Applicants appreciate the courtesy of the in-person interview conducted by Examiner Lish on November 15, 2005, and the subsequent telephone conversations. In view of these, the Applicants have canceled claim 3, and have amended claim 1. New claims 15-21 have also been added.

Claim 1 has been amended to incorporate the subject matter of claim 3; *i.e.*, that the Fe-S compounds are precipitated onto the particles, and to specify that the amount of manganese in the iron powder is 0.06 % or less by mass. Support for the amendments to claim 1 is found in paragraphs [0020], [0023], [0030] and [0031]. Claim 3 has been canceled as redundant.

Support for new claim 15, which depends from claim 1 and specifies that the water-atomized powder is non-reduced, is found in paragraph [0033]. Support for new claim 16, which specifies that the iron powder of claim 13 is produced by water-atomization, is found in paragraph [0041]. Support for new claim 17, which depends from claim 1 and specifies that the degree of surface precipitation of the Fe-S based inorganic compounds is 10 or more as measured for the number of particles per  $250 \mu\text{m}^2$ , is found in paragraph [0060] and Table 1.

New independent claim 18 has also been added, which is directed to a method of remediating media contaminated with halogenated hydrocarbons, comprising precipitating Fe-S based inorganic compounds onto iron powder by water atomization of molten steel of the composition and then contacted with the contaminated media to reduce the halogenated hydrocarbons. Support for new claim 18 is found in paragraphs [0020], [0023], [0030], [0041] and original claim 1.

New claims 19, 20 and 21, specify that the sulfur content of the iron particles in independent claims 1, 13 and 18, respectively, is about 0.1 to about 0.4%. Support for these claims is found in Table 1.

Claims 1, 3, 5-9 and 13 are rejected under 35 U.S.C. §103 as allegedly rendered obvious by Hassan. Claim 3 has been canceled without prejudice, as the subject matter of this claim has been incorporated into claim 1. The rejection is therefore moot as to this claim. The Applicants note the comments on page 2 of the Official Action as to the continued application of Hassan against those claims. Nonetheless, the Applicants respectfully submit that a complete reading of the Hassan disclosure, coupled with the exact claim language in Claims 5-9 and 13 as amended will reveal that Hassan utterly fails to disclose, teach or suggest the subject matter of those claims.

The Applicants will address the comments on pg. 2 of the Office Action in two parts, in the

same manner that they are presented. The first portion of those comments are as follows:

First, it is seen that even if the teaching of Hassan were restricted to the mixing of iron powder and iron sulfide powder, it would still meet the limitations of the instantly claimed invention. The present claims do not provide a limitation as to where the sulfur comes from, rather the claims require a specific sulfur content of a composition of “iron powder” and that a portion of the surfaces of the iron powder contain sulfur. Should the “iron powder” be interpreted as a mixture of pure iron powder and iron sulfide powder, it is seen to meet the claim limitations.

The comment reproduced above fundamentally contains two different points. The first point is with respect to the composition of the “iron powder.” Claim 1 as amended recites an “iron powder containing about 0.1 to about 2% by mass of sulfur and about 0.06% by mass or less of manganese as the composition, based on the mass of the iron powder.” What this means to those of ordinary skill in the art is that the iron powder particles contain the claimed percentage by mass of sulfur and the claimed percentage of mass of manganese in addition to iron, as the composition that forms the iron powder particles. Said differently, the particles or powder is of a *composition* that contains iron, the claimed amount of sulfur and the claimed amount of manganese. Accordingly, the iron powder is not a mixture of pure iron powder and iron sulfide powder.

The claimed iron powder is thus utterly different from Hassan. Hassan in no way discloses, teaches or suggests iron powder particles containing iron, the claimed amount of sulfur and the claimed amount of manganese. Instead, Hassan discloses different powder materials. Hassan specifically discloses two types of iron that may be used, namely laboratory-grade iron filings obtained from Fisher Scientific Company of Pittsburgh, Pennsylvania and extra pure iron powder obtained by AESAR of Ward Hill, Massachusetts.

The extra pure iron taught in Hassan has a sulfur content of 20.1 *ppb*, and the iron filings have a sulfur content of 180.5 *ppm*. As such, the iron filings taught in Hassan have a very low sulfur content, while the extra pure iron powder has an extremely low sulfur content, as compared to the claimed iron powder. Such very low and extremely low sulfur contents are typical of the prior art previously employed in attempts to remediate media contaminated with halogenated hydrocarbons.

The extra pure iron and iron filings in Hassan were mixed with ferrous sulfide produced from sodium sulfide and ferrous sulfate, which resulted in ferrous sulfide being deposited on the iron particles. These iron particles with Fe-S deposited onto their surface were utilized to reduce the halogenated hydrocarbons.

Such a process has nothing to do with the claimed process. This is because Hassan took a

completely different approach to the introduction of sulfur into a reaction intended to reduce the halogenated hydrocarbons. Specifically, Hassan took very low sulfur-content iron and extremely low sulfur-content iron, separately added ferrous sulfide to produce particle with Fe-S deposited (but not precipitated onto) its surface, and then utilized the mixture in an attempt to reduce the halogenated hydrocarbons.

This is sharply different from the claimed process, wherein iron powder containing about 0.1 to about 2% by mass of sulfur was employed in a water atomization process to produce the reductive iron particle, and the sulfur from the iron powder particles themselves was the source of the sulfur, and not an external source of sulfur (*i.e.*, from separately added ferrous sulfide).

The differences between the Hassan iron particle and the presently claimed iron particle is demonstrated by a direct comparison between the content of the iron powder particles specifically claimed by the Applicants versus the content of sulfur in the iron filings and extra pure iron powder of Hassan. For example, the iron filings of Hassan had a sulfur content of 180.5 ppm. This is contrasted to the sulfur content claimed by the Applicants. In that regard, the Applicants note that the claimed about 0.1% by mass of sulfur is the same as about 1,000 ppm of sulfur contained within the iron powder itself. The iron filings of Hassan have a sulfur content of 180.5 ppm, while the minimal amount of sulfur contained within the powder of the Applicants' invention is about 1,000 ppm. In other words, the Applicants' claimed iron powder contains five times more sulfur within the particles of the iron powder than the iron filings of Hassan.

Thus, the Applicants provide particles with sulfur precipitated on at least portions of the particle surface by using sulfur from within the powder to form particles via the water atomization method. This is sharply contrasted to Hassan, who separately adds ferrous sulfide to the very low sulfur content iron filings such that the sulfur is simply deposited on the iron particle surface. The differences are still further illustrated as one progresses upwardly through the Applicants' claimed range of sulfur content up to about 2%. This results in a drastically higher sulfur ppm content as claimed by the Applicants, which becomes about 100 times greater than the sulfur content of the Hassan iron filings.

The differences become even more dramatic when referring to the extra pure iron powder of Hassan which has a sulfur content of 20.1 ppb. Note that the drastic differences set forth above with respect to the iron filings were parts per Million. In the case of the extra pure iron powder of Hassan, the sulfur content is measured in parts per Billion. It can then be readily seen that the differences in

the sulfur content as claimed by the Applicants versus the sulfur content of the iron powder of Hassan are different by orders of magnitude. It is therefore clear that the claimed iron powder is completely different from the iron powder of Hassan.

Moreover, the sulfur which is deposited on the surface of the Hassan particles does not form an integral part of the iron particle, and can be washed away by large volumes of aqueous solutions or gasses. Thus, the Hassan particles are not suited for environmental remediation of soils, water and air, as the deposited sulfur compounds would require replenishment from an outside source. In contrast, the water atomization method as claimed by the Applicants results in the precipitation of Fe-S compounds on the iron particle surface. Such precipitates form an integral part of the iron particle, and cannot be removed by large volumes of liquid or gas. Thus, one skilled in the art would not be motivated to use the Hassan particles for soil, water and air remediation, as recited in the presently claimed methods.

Evidence that the sulfur compound precipitates form an integral part of the iron particle, and that such precipitates impart unique characteristics to the particles, can be seen from an analysis of the data presented in the Table 1 of the Applicants' specification vs. the data presented in Table 1 of Hassan.

This comparison shows that the dehalogenation rate for particles of the invention is far superior to that of Hassan; see rows "per day ( $d^{-1}$ )" in Comparison Figure A (attached hereto), which are framed by broken heavy lines).

The dehalogenation rate may be affected by the amount of the aqueous phase and the amount of iron powder (more strictly, the total surface area of the iron powder particles). This difference has been roughly compensated for by multiplying the dehalogenation rate by the ratio of aqueous phase to iron powder; see the rows of "compensated by aqua/powder ( $L \cdot d^{-1} \cdot kg^{-1}$ )" framed by heavy lines. The result (dehalogenation rate) is plotted vs. S content\* in Comparison Figure B (attached hereto). Even taking the aqueous phase/iron powder ratio in consideration, the dehalogenation rate for the iron particles of the invention is remarkably high, especially in the range of around 0.1 to 0.5 mass% of S. The difference in dehalogenation rates between the Applicants' particles and those of

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\* It was assumed that every S of the NaSH used by Hassan was deposited on the iron powder particles. This is likely an overestimation, but a similar overestimation was used to determine the S amount precipitated onto the particles of the invention (e.g., not all the S compound precipitates are formed on the surface of the iron powder particle; some are formed inside the particle). Therefore, this estimation for the S amount deposited on the Hassan particles is justified.

Hassan is likely due to the fact that precipitated S compounds are stably attached to the surface of the Applicants' particles. Thus, the S compounds precipitated onto the Applicants' particles are integral to the particles, whereas the S compounds deposited on the Hassan particles are not integral and are readily washed away. The Applicants' particles therefore have a greater dehalogenation than the particles taught by Hassan.

Referring back now to the first portion of the above quoted comment from pg. 2 of the Office Action, it becomes apparent that Hassan does not meet the limitations of the rejected claims. The powders are completely different.

The Office Action has provided additional helpful comments concerning the theoretical application of Hassan to the claims. Those comments are set forth as below:

Secondly, and more importantly, the teaching of Hassan is not restricted as such. Rather, on page 1361, Hassan teaches the precipitation of sulfur on pure iron powder by treating the iron powder with hydrochloric acid. Hassan also teaches the formation of iron sulfide by the addition of sodium hydrogen sulfide to the iron powder. Both of these methods yield the pure iron powder having increases sulfur content on its surface. It is not seen how this differs from the powder of the presently claimed invention.

The above-quoted passage alleges that Hassan "teaches the precipitation of sulfur on pure iron powder by treating the iron with hydrochloric acid." The Applicants respectfully submit that page 1361 of Hassan discloses two things. The first is that two types of experiments were conducted. The first experiment is washing extra pure iron with hydrochloric acid. The other experiment is inclusion of sodium hydrogen sulfide with extra pure iron. The result of these two processes is hydrochloric acid washing of extra pure iron as set forth in the table at the bottom of the left hand column of page 1361. On the other hand, the inclusion of sodium hydrogen sulfide with the extra pure iron results in the formation of hydrogen sulfide which is subsequently "deposited" (as opposed to precipitated) within pits on the surface of the iron. The Applicants therefore respectfully submit that there is utterly no disclosure, teaching or suggestion concerning "precipitation of sulfur on pure iron powder by treating the iron powder with hydrochloric acid." The treatment of iron powder with hydrochloric acid in no way results in precipitation of sulfur on the pure iron powder. Instead, it merely results in acid washed extra pure iron. Even in the case where there is formation of hydrogen sulfide, this

results in deposits of ferrous sulfide on the iron powder surfaces which can be readily dislodged during environmental remediation. There is no “precipitation.”

In any event, deposition of ferrous sulfide on the surfaces of the iron is not the same as what is claimed in the rejected claims. Claim 1 as amended, claim 13 and new independent claim 18 specifically call for forming Fe-S based inorganic compounds mainly comprising sulfur on at least portions of surfaces of iron powder that contains about 0.1 to about 2% by mass of sulfur, wherein the sulfur is derived from the iron powder and is precipitated onto the iron particles. The Applicants respectfully submit that Hassan fails to disclose, teach or suggest this. Even though Hassan suggests deposition of Fe-S based inorganic compound on portion surfaces of iron powder, this is not formation of Fe-S based inorganic compounds on iron powder that in and of itself contains sulfur in the claimed amounts. It has already been established that the ferrous sulfide deposited on the iron surface in Hassan is deposition of externally-derived ferrous sulfide on extra pure iron. That is not the same as formation of Fe-S based inorganic compounds on iron powder that contains sulfur. In other words, the claimed iron powder is not the extra pure iron of Hassan, but instead, is iron containing sulfur in the claimed amounts.

As a consequence, at best, Hassan on page 1361 teaches deposition of ferrous sulfide on the surface of extra pure iron. That is not what the Applicants claim in the rejected claims. The Applicants amended claims recite the formation of Fe-S based inorganic compounds on iron powder that already contains sulfur, by the water atomization method. Thus, even if one of ordinary skill in the art were to look to Hassan, the resulting teachings would still fail to lead one of ordinary skill in the art to the subject matter of the rejected claims.

The above quoted passage from the Office Action also alleges that both methods yield the pure iron powder having increased sulfur content on its surface. The Applicants respectfully submit that this is not the case. Hassan results in pure iron powder having increased sulfur content on its surface. However, the subject matter of the recited claims does not result in such a pure iron powder. Instead, the Applicants’ process yields an iron powder containing sulfur with an increased sulfur content on its surface. These are not the same, and the Hassan powder is in no way suggestive of the powder recited in the rejected claims. The Applicants therefore respectfully submit that Hassan is inapplicable to independent claims 1 and 13 and new claim 18.

Claims 1, 3, 5-9 and 13 are rejected under 35 U.S.C. §103 as allegedly rendered obvious by the hypothetical combination of Hassan with Wolfe. Claim 3 has been canceled without prejudice,

as the subject matter of this claim has been incorporated into claim 1. The rejection is therefore moot as to this claim.

Hassan is discussed above. Wolfe teaches methods of remediating environmental contaminants in soil, water, etc., with comminuted commercial grade iron. Although Wolfe teaches that the commercial grade iron can be used alone, since it contains a certain amount of sulfur, “for enhance reaction kinetics, an additional sulfur source . . . should be added to the commercial iron.” See Wolfe, col. 6, lines 36-39. As discussed above for Hassan, commercial grade iron contains sulfur on the order of about 180 parts per million. The iron particles used in the claimed method contains many times that amount of sulfur. Wolfe, like Hassan, teaches that sulfur above the amount contained in the commercial grade iron should be derived from outside sources. Here, independent claims 1 and 13, as well as new claim 18, specifies that the sulfur is derived internally.

Moreover, dependent claim 14 and (new) claim 16, and new independent claim 18 specify that the iron particles are formed by the water atomization method. Neither Hassan nor Wolfe teach or suggest the use of the water atomization method on iron particles which contain the amounts of sulfur as recited in these claims. Thus, the Applicants respectfully submit that the hypothetical combination of Wolfe and Hassan still would result in a relatively pure iron powder having increased sulfur content deposited on its surface, which is not what the Applicants have claimed. Instead, the Applicants claim an iron powder having a significantly higher sulfur content than the particles taught in Hassan and Wolfe, which has sulfur compounds precipitated (rather than deposited) on its surface. Again, these are not the same. Therefore, even if one of ordinary skill in the art were to combine Hassan with Wolfe, the resulting methodology and iron particle would be quite different. Withdrawal of the rejection is respectfully requested.

Claim 14 is rejected under 35 U.S.C. §103 as allegedly rendered obvious by the further hypothetical combination of JP'725 or Uenosono with Hassan and Wolfe. Claim 14 and new claim 16 (which are dependent on claim 1) and new claim 18 all recite that the particles are formed, and the Fe-S compounds are precipitated onto the particles by, the water atomization method. The iron particles recited in these claims have about 0.1 to about 2% by mass of sulfur and the precipitated Fe-S compounds are derived from the iron particles themselves.

As discussed above, Hassan and Wolfe do not teach or suggest the formation of an iron particle with Fe-S compounds precipitated on its surface by the water atomization method, where the iron particles have about 0.1 to about 2% by mass of sulfur and where the Fe-S compounds are

precipitated with sulfur derived from the iron particles themselves. While JP'725 and Uenosono show that iron particles containing sulfur can be subjected to the water atomization method, there is no teaching or suggestion to use iron particles with about 0.1 to about 2% by mass of sulfur. Rather, JP'725 produces an iron particle with 0.08-0.3% sulfur content, and Uenosono produces an iron particle with 0.05-0.4% sulfur content.

As discussed above, neither Hassan nor Wolfe teach that the internal sulfur content of an iron particle could or should be about 0.1 to about 2% by mass, as recited in claim 13. On the contrary, both Hassan and Wolfe teach that any sulfur required in addition to that found in commercial grade iron should be supplied externally. Thus, the hypothetical combination of JP'725 or Uenosono with Hassan and Wolfe teaches away from subjecting iron particles having higher sulfur content to the water atomization process, in order to produce iron particles for environmental remediation. Instead, these references would motivate one skilled in the art to derive extra sulfur from an external source.

Thus, the Applicants respectfully submit that hypothetically combining the teachings of JP'725 or Uenosono with either or both of Hassan and Wolfe would fail to teach or suggest the method of claim 14. Likewise, new claims 16 and 18 are also patentable over the hypothetical combination of JP'725 or Uenosono with either or both of Hassan and Wolfe. Withdrawal of the rejection is respectfully requested.

New dependent claims 19-21 have been added, which specify that the sulfur content of the iron particles in independent claims 1, 13 and 18, respectively, is about 0.1 to about 0.4%. Iron particles with a sulfur content in this range appear to be particularly useful for dehalogenating contaminated compounds, based on the results shown in Table 1 (see also the comparative results in Comparison Figures 1 and 2, discussed above). Neither JP'725 nor Uenosono teach or suggest making iron particles that have the S content as recited in new claims 19-21, nor do they discuss any advantages in doing so. Thus, new claims 19-21 are not obvious over JP'725 nor Uenosono, either alone or in combination with Hassan and Wolfe.

In light of the foregoing, the Applicants respectfully submit that the entire Application is now in condition for allowance, which is respectfully requested.

Respectfully submitted,



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